Chapter 5 – The Methodology: Assessing Possible Futures

Preparing a long-term power plan requires many assumptions about the future. These assumptions (forecasts) are important for setting a context for evaluating different types of resources. This chapter outlines key components of the base forecast (also called the "reference" forecast) and describes four alternative scenarios to the reference forecast. Along with the reference forecast, these four scenarios were used to evaluate potential portfolios of power resources, using the criteria of reliability, cost, risk and environmental impact.

The computer model used to evaluate the portfolios is described, including sample output and constraints. The final section lists the resources used in various combinations during two rounds of portfolio analysis.

Defining the Reference Forecast

The focus of City Light's resource planning is on the Pacific Northwest. However, power price forecasts are driven by the much broader Western wholesale power market, in which City Light conducts power transactions (see Chapter 4). The Western power market is commonly influenced by such diverse factors as high summer temperatures in the Southwest and cold winter temperatures in the Northwest; transmission constraints in various locations in the West; precipitation levels in the Pacific Northwest; nuclear plant outages in California; coal plant outages in Montana, Wyoming or Utah; natural gas deliveries from Alberta, Canada; and power imports to the U.S. from Canada or Baja, Mexico.

Assembling forecasts of future market conditions is an important part of resource planning. However, there is a wide range of viewpoints about future energy market conditions, including factors such as the pace of economic growth, available generation, fuel supplies and costs for generators, regional electricity demand, power prices and greenhouse gas policies.

Objectivity and logical consistency in forecast assumptions are important to resource planning. Accordingly, City Light chose to use independently developed forecasts from Global Energy Decisions (GED), Inc. for evaluating future electricity market conditions in the Pacific Northwest and the Western United States. The following discussion describes the Reference Case – the forecast conditions related to fuel prices, resource supply and electricity prices that GED believes to be most likely.

Fuel Prices

Fuel prices are an important input into a power price outlook because they are a major determinant of generator costs to produce power. In a competitive power market, fuel prices can drive rapid changes in power prices. This section gives an overview of the fuel price forecasts used in the IRP.

Natural Gas

The market for natural gas in the Pacific Northwest is heavily influenced by national market trends because of the national network of natural gas pipelines. Unlike electricity, an extensive and interconnected pipeline system makes it possible to move natural gas from one end of the country to the other. Natural gas-fired generation plays a particularly important role in the West because it is usually the last generating unit to be dispatched (known as the "marginal unit"). Lower cost resources will be dispatched before natural gas-fired generation resources, in the absence of transmission constraints or reliability concerns.

The cost of dispatching the marginal unit frequently sets the short-term power price in the Western wholesale power market, so that the short-term (spot) power prices seen by City Light are highly correlated with price of natural gas. Given the inherent volatility of its own hydro resources and of electricity demand, City Light must buy from or sell into the power market to balance its power supply. Thus, even though City Light presently has no natural gas-fired generation, the price of natural gas will continue to be an important factor in determining City Light's wholesale power costs and revenues.

In GED's Reference Case forecast for this IRP, future natural gas prices fall considerably from first quarter 2006 levels by 2009, ranging from an annual average of $4.31 per MMBTU in 2009 to $4.94 per MMBTU in 2026 (2006 dollars). In the forecast, the following factors are important in moderating natural gas prices from early 2006 levels:

- Natural gas drilling platforms and pipelines in the Southeastern U.S. damaged by Hurricane Katrina are repaired.
- New import terminals for liquified natural gas (LNG) are constructed at ports in the United States and Mexico, allowing foreign natural gas supplies to bolster declining North American natural gas production and reserves.
- Growth in generation from resources other than natural gas helps to temper the need for more natural gas for power generation.
- In the long run, fuel prices will be influenced less by financial speculation in commodity markets and more by the market fundamentals of supply and demand.

Coal

Coal-fired generation is not as important in the Pacific Northwest as in other parts of the West, but it commonly influences Pacific Northwest power prices in light load hours. Also, because it is dispatched ahead of natural gas-fired generation, significant changes in coal-fired generation lead to the operation of more efficient or less efficient natural gas-fired generators, which influences Pacific Northwest prices in heavy load hours.

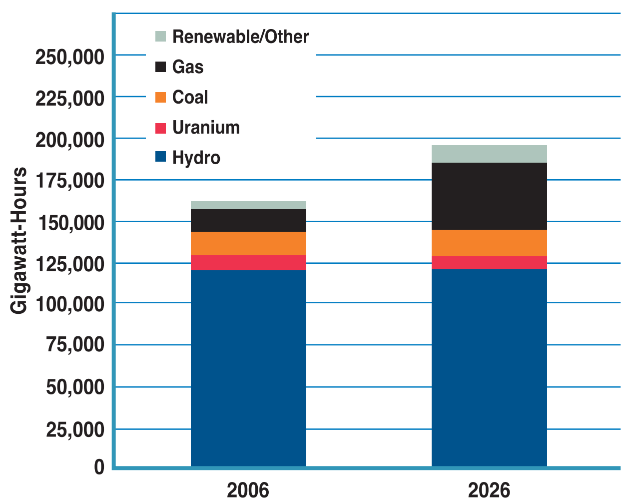
In the GED reference forecast, coal remains the single most important resource in the Western United States with respect to energy supplied for the next 20 years. Today it makes up nearly 40 percent of all electricity generation in the West. Absent costs for control of carbon dioxide, it is forecasted to continue to be a large and stable source of base-load generation.

Coal prices in the forecast grow at an average annual rate of 0.56 percent in real terms over the 20-year forecast period. At approximately $1.79 per million Btu today, it is expected to average $2.00 per ton by 2025 (in 2006 dollars). It should be noted that the GED reference forecast does not assume a carbon tax or a carbon dioxide emissions cap within the next 20 years. City Light examined the risks of a carbon tax or emission cap on coal-fired generation through scenario analysis.

Resource Supply

GED's Reference Case forecast for the Pacific Northwest used in this IRP indicates that most growth in Western power resources will come from natural gas-fired generation. Hydro, nuclear and coal-fired resources are forecast to remain relatively constant, while natural gas grows from 14,126 GWh in 2006 to 40,581 GWh in 2026, at an average annual rate of 5.4 percent. Renewables also see significant growth, from 4,821 GWh in 2006 to 10,551 GWh in 2026, an average annual rate of 4.0 percent. This forecast is illustrated in Figure 5-1.

Figure 5-1. Fuel Mix in the Reference Case



Source: Global Energy Decisions

Forecast

In 2006, most parts of the West have surplus generating capacity, including the Pacific Northwest. GED forecasts that demand in the Pacific Northwest will grow at an average of 2.3 percent annually, which is faster than the rate forecast for the City of Seattle. The Reference Case forecast estimates that the Pacific Northwest will have more than adequate reserves to meet a 12 percent recommended reserve margin for the next decade under normal conditions.

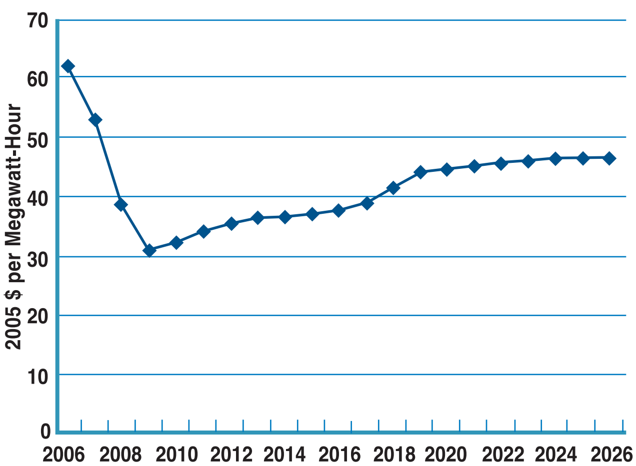
It is assumed that all City Light owned resources will continue to operate through the forecast period. Power purchase contracts are assumed to expire according to contract terms, and the BPA is assumed to continue supplying power to City Light from the Federal Columbia River System at cost-based rates.

Electricity Prices

Electricity price forecasts are used to evaluate the costs of buying power and the revenues from selling power. They determine when it is economic to make sales or to make purchases.

Spot prices for wholesale power in the Pacific Northwest are used in modeling, as shown in Figure 5-2. Following a forecasted annual average natural gas price decline from 2006 to 2009, the forecasted real price of on-peak power also falls to $31, then grows from 2009 to average $47/MWh (real 2005 dollars) by 2026. The market price decline mirrors the forecasted decline in the cost for natural gas. Since natural gas-fired generation is on the margin most of the time in the West, the spot market price and the price of natural gas tend to move in tandem.

Figure 5-2. Pacific Northwest Average Wholesale Power Prices, All Hours (Real Dollars per Megawatt-Hour)



Source: Global Energy Decisions

Envisioning Alternative Futures

While GED sees the Reference Case as the most likely future, significantly different conditions may occur. To consider alternatives to the Reference Case, variations were described as alternative future conditions, or "scenarios".

These scenarios, described below, are sets of internally consistent predictions of political trends, economic growth, regulation, technology and environmental policies. As a way of addressing uncertainty, GED developed alternative forecasts of fuel prices, power prices, electricity supply and demand that are consistent with each of the four scenarios.

Even though events are unlikely to unfold exactly as envisioned in any of the scenarios, they are designed to bracket a wide range of conditions that might reasonably be expected. GED supplied all forecasts for the scenarios over the 20-year planning period.

Scenarios: A Range of Possible Future Conditions

Each alternate scenario has a theme that is taken to its logical conclusion in terms of national environmental policy, energy policy, market forces and geopolitics. The scenarios are named Green World, Nuclear Resurgence, Return to Reliability, and Terrorism and Turmoil.

Detailed assumptions are built into each scenario about market factors such as fuel supplies, energy pricing, electricity prices, electricity demand and electricity supply in the Pacific Northwest. Table 5-1 lists the key features of each scenario.

Table 5-1. Scenarios and Key Themes

	Green World	Nuclear Resurgence	Return to Reliability	Terrorism & Turmoil
Fuels	• Need for LNG cannot be met due to inadequate gasification facilities • Coal hit hard by tightening regulations • Big push to renewable resources	• Gas and oil prices constrained	• Supply and demand for natural gas and LNG well-matched	• LNG & oil supply constrained • Higher price plateau for long term • Coal is "king" • Renewables benefit from high prices and government support
Energy Pricing	• Gas prices rise with tight supply • Power prices rise with stricter environmental controls on coal	• Gas and oil prices rise with tight supply • Prices recover after surge of nuclear builds reduces demand	• Oil and gas prices fall back to normal levels	• Gas and oil prices spike and remain high • Increase in fuel and security costs outweigh fall in demand
Economy/ Energy Demand	• No recession but low growth rates • Energy demand is down – hit by higher energy costs • Slow economic growth, and greater conservation	• Economic growth booms • Increased energy demand	• Economic growth continues at current expectations • Energy demand remains normal	• Recession and slow recovery – hit by higher energy and security costs • Lower average growth • Energy demand falls
Market Structure	• Restructuring slows – patchwork • Mix of utilities and independent power producers • Liquidity is flat • Slow recovery to overbuild	• Restructuring continues • Nuclear consortium agrees on operational pact	• Restructuring comes to halt • Reliability standards adopted • Investment in transmission infrastructure	• Restructuring comes to halt, patchwork market • Priority on security and reliability • Utilities advantaged over independent power producers • Liquidity dries up
Environment	• 5 Pollutants: SO_2, NO_x, PM2.5, and mercury phased in • Flexible market mechanisms relied upon • CO_2 reduction phased in from 2010 • Limited access to federal lands for exploration	• 5 Pollutants: SO_2, NO_x, PM2.5, and mercury phased in • Flexible market mechanisms relied upon • CO_2 reduction phased in from 2014	• Existing NO_x and SO_2 regulations enforced • Flexible market mechanisms relied upon • No federal CO_2 regulations	• Existing NO_x and SO_2 regulations enforced • Flexible market mechanisms relied upon • No federal CO_2 regulations • Federal lands open to oil & gas exploration

Source: Electric Power Horizons: Scenarios of the Global Energy Future-2005, Global Energy Decisions.

Future Generating Capacity and Fuels

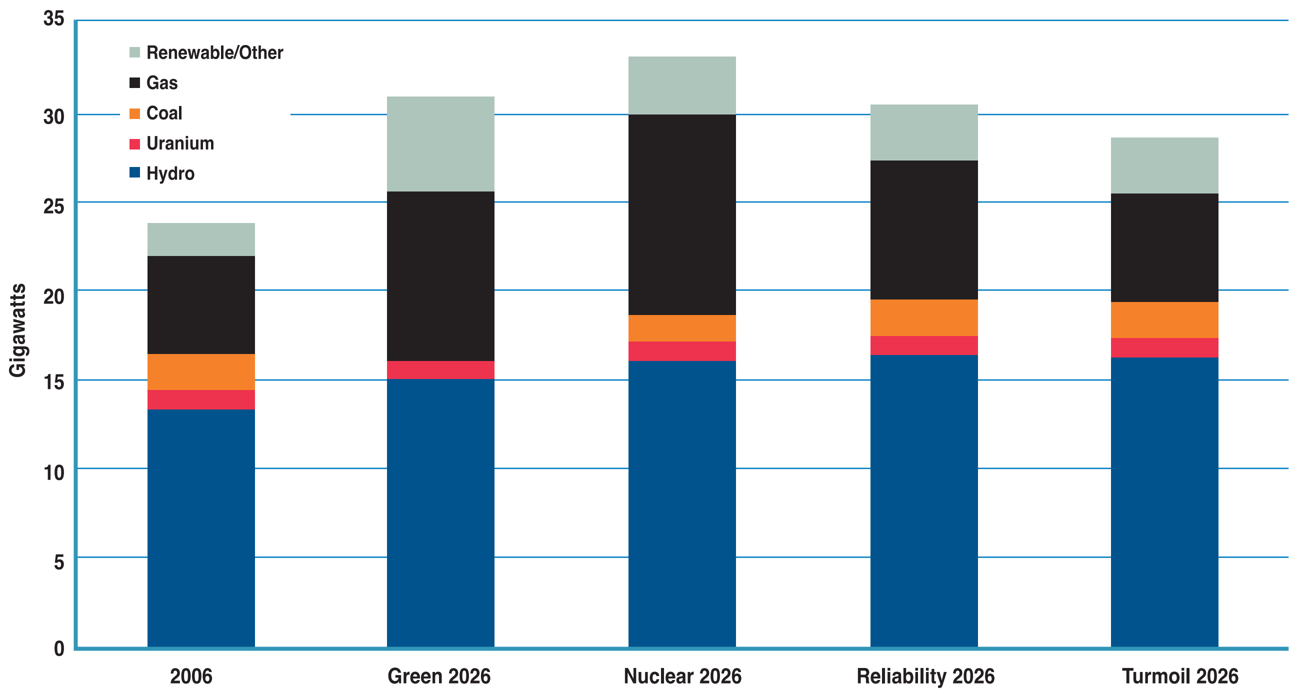
Applying their assumptions for each scenario over the next 20 years, GED arrived at four different fuel mixes available for Northwest power generation. The capacity of renewable resources increases under all scenarios, more than tripling for Green World and almost doubling for the others. This is perhaps a reflection of the successful application of Renewable Portfolio Standards (RPS) by state governments.

Renewable resources are about 17 percent of total capacity for Green World and about 10 percent in the other scenarios. Gas-fired capacity increases substantially under all scenarios as a consequence of siting liquified natural gas (LNG) facilities. Coal is completely eliminated in Green World, decreases by about a fourth in Nuclear Resurgence, and stays the same in the other two scenarios. Oil-fired generation, nuclear power (uranium), and hydro capacity see no growth in any of the scenarios.

Figure 5-3 shows the electric generation capacity and fuel mix for each future in 2026, compared to 2006.

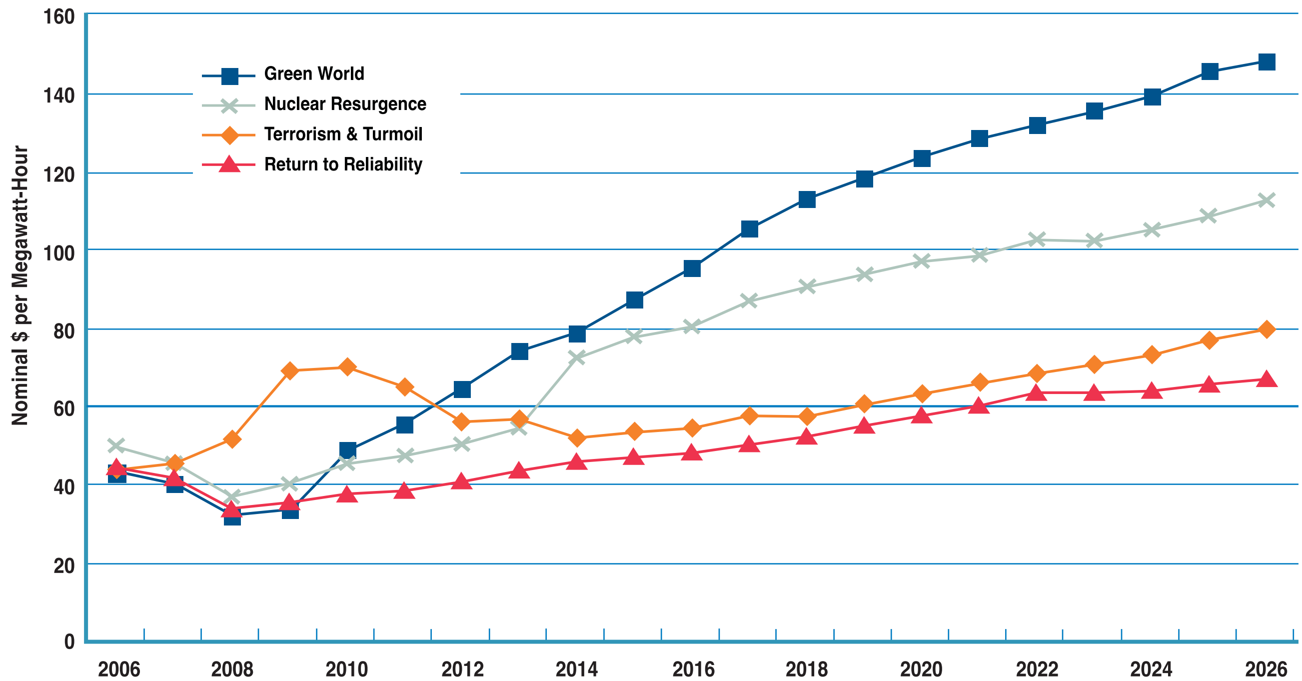
For all scenarios, natural gas is the fuel source that increases by the greatest amount in terms of output. Coal remains about the same in the Return to Reliability and Terrorism & Turmoil scenarios. Green World looks least like the other scenarios by 2026. In Green World, coal has been eliminated primarily through emissions regulation and national Renewable Portfolio Standards. The cost of meeting regulations makes power costs for Green World very much higher than for the other three scenarios.

Figure 5-3. Electric Generation Capacity by Fuel Source in WECC NW



Source: Global Energy Decisions

Figure 5-4. WECC NW (Mid-C) All-Hour Average Wholesale Electricity Price, 2006-2026



Source: Global Energy Decisions

Power Prices in the Four Scenarios

For each scenario, Figure 5-4 shows the change in power price in the WECC Northwest (Mid-Columbia) over the period from 2006 to 2026.

Defining Evaluation Criteria

City Light staff established four criteria for evaluating alternative resource portfolios:

- Provide reliable service
- Minimize cost to customers
- Manage risks
- Minimize environmental impacts

To quantify the expected performance of each candidate resource portfolio in meeting each criterion, City Light chose specific measures, listed in Table 5-2 and described on the following pages.

Table 5-2. Criteria and Measures for Evaluating Resource Portfolios

Criteria	Measures
Provide Reliable Service	Occurrence of unserved customer energy need.
Minimize Costs to Customers	20-Year net present value of portfolio costs.
Manage Risks	Volatility of portfolio costs (net revenue).
Minimize Environmental Impacts	Air emissions of CO_2, SO_2, NO_x, mercury, and particulates. Impacts on land use, surface and groundwater, soils and geology, plants and animals, employment, aesthetics and recreation, environmental health, and cultural and history were also evaluated in the EIS.

Provide Reliable Service

A critical part of City Light's mission is to provide reliable service – meaning electricity is available when customers want to use it. Electricity is a necessary part of modern life, and is critical to health, safety and economic security. Failure to provide reliable power has serious, immediate consequences, and City Light has procedures in place to ensure that it is able to provide power or restore power quickly when needed.

The main requirements for providing reliable service are that:

- Enough power is being generated to meet the demand.
- Sufficient transmission infrastructure is available and functioning properly to bring the power to City Light's service area.
- Sufficient distribution infrastructure is available and functioning properly to bring the power from the transmission system to the customer.

IRPs usually focus on meeting a high standard of reliability for power supply and do not address availability of transmission and distribution. However, in this IRP, transmission is evaluated for all potential new resources, including transmission availability and the likelihood and cost of building new transmission.

The distribution aspects of reliability are not considered quantitatively in the IRP, with one exception. Energy savings from conservation programs are assumed to have some benefit in deferring investment in new distribution infrastructure. To quantify these benefits, the cost of all energy efficiency measures assessed in the IRP was reduced.

The reliability of power supply depends on:

- Adequacy of generating capacity to meet demand (resource adequacy).
- Adequacy of fuel (e.g. natural gas, coal, water) to generate the energy needed.
- Operational capability of the generating facility.

The question of whether there is enough generating capacity was evaluated in the IRP through the resource adequacy analysis described in Chapter 3. The resource adequacy analysis is an important step in determining the amount of resources needed, and when the resources are needed to meet the reliability standard.

In the resource adequacy analysis, City Light compared energy demand to the energy available from its owned and contracted resources, and a limited amount of market resource (see Chapter 3). Over 1,000 possible combinations of hydropower outputs (a critical issue given City Light's dependence on hydropower) and load were considered, and each combination was evaluated by month over the 20-year planning period.

In addition to ensuring an adequate amount of generating capacity, the sufficiency of the fuel, and the operational reliability of the resource must be considered. Each type of resource has its own fuel and operational uncertainties. For example:

- Hydropower depends upon precipitation, snowmelt and variations in the timing of the migration and spawning cycles of fish. Hydroelectric generation in the Northwest produces power between 45 and 65 percent of the time. Hydroelectric resources are the most flexible and least cost resources available for following load.
- Most coal plants in the West are located near the mine, so access to fuel is highly certain. Unexpected outages are relatively rare, and most western coal plants operate 85 to 90 percent of the time.
- Wind farms are able to produce electricity only when the wind blows. While generating units are highly dependable, the wind is not. Northwest wind generating plants produce power on average about 32 percent of the time, according to the Northwest Power and Conservation Council.
- Natural gas combined cycle plants sometimes face fuel supply issues, particularly in high demand periods, but this is not common when a plant is operated to meet a utility's firm load. More recently, their operations have been limited by the periodic high price of natural gas. Typically these resources can generate electricity over 90 percent of the time.

In modeling candidate resource portfolios, these uncertainties are addressed by introducing variability of hydro operations, wind patterns and forced outages. If correctly constructed, each candidate portfolio is able to meet the 95 percent resource adequacy criteria despite the above challenges. In effect, the reliability criterion is "hard-wired" by design into the resource portfolio. Each portfolio can then be examined for the number of hours of unserved energy occurring to verify it is meeting the reliability criteria.

Minimize Costs to Customers

A fundamental policy issue is balancing the cost of providing service with providing reliable service. In real terms, the cost of electricity declined in the Northwest for decades until about 1980. Even now, the Northwest enjoys the lowest cost power supply in the country due to its reliance on hydroelectric generating plants. Factors influencing cost vary for each type of resource, as described in Chapter 4.

In calculating the costs of specific resources, the IRP assumes that City Light will contract to buy the output of a resource through a power purchase agreement. Whether it is more advantageous to own a resource rather than contract for its output will be determined at the time the Utility is ready to acquire a resource and has received cost information for both approaches through competitive bidding. The exceptions are those resource alternatives that are based on contracting for energy, such as seasonal exchanges and call options.

Costs in the IRP are evaluated over the entire resource portfolio. For example, a higher cost resource may be included in small amounts in a portfolio, and that small addition can help City Light avoid investment in a much larger resource that may have lower per unit of energy costs, but higher overall costs.

The measure chosen for this criterion is 20-year net present value (NPV) of portfolio costs. The net present value accounts for the costs of the resources through time (including capital, operation and maintenance costs, fuel and financing costs) and revenues received from selling unneeded energy.

Manage Risk

Current practice in integrated resource planning emphasizes identifying and analyzing sources of risk. Many forms of risk are evaluated in the IRP; some quantitatively, and some qualitatively. Risks that can be quantified include:

- Variations in demand for electricity (City Light's load) due to factors such as weather and economic conditions.
- Generation plant output, particularly hydropower, where output can vary widely from year to year and month to month, depending on precipitation and snowmelt patterns or wind where output can vary widely from hour to hour and day to day.
- Prices for electricity on the wholesale market.
- Cost of fuel such as natural gas.
- Potential cost of complying with environmental regulations, particularly emissions.

Evaluating these risks does not guarantee that they can be determined exactly, but it does define a range of possible risk and associated costs.

Other types of risk can be more difficult, and sometimes impossible, to quantify. These include the potential for regulatory or policy changes that could affect the availability and cost of resources, policies related to transportation of fuels by pipeline or rail, and requirements related to resource and transmission adequacy.

One of the most significant types of risk that City Light deals with is the uncertainty of the cost of purchasing power or the revenues from selling power into the wholesale power market. These transactions can involve hundreds of millions of dollars annually, and the magnitude of wholesale revenues and purchases can swing by more than $100 million from year to year. As described in Chapter 4, City Light participates in the market for a variety of reasons; for example buying electricity to help meet demand during low water conditions, and using the energy storage capability at its hydroelectric projects to purchase low priced energy and store water for use later when prices are higher. Currently, City Light sells much more electricity into the market on an annual basis than it purchases, primarily because it requires more resources to meet the three-month winter peaking load requirement than are needed during the remaining nine months of the year.

Because City Light's hydro output varies so dramatically from year to year, and because so many factors determine future market prices, the Utility has developed strategies to mitigate the risk. One of the primary goals of the IRP is to illustrate the trade off between these risks and the other criteria, such as cost and reliability. The IRP does not provide "the answer", but shows how certain portfolios can result in more or less risk, and illustrates the options.

Mitigating the risk of buying and selling electricity in the market occurs in three stages:

- Designing a low-risk resource portfolio, one of the primary goals of the IRP process. This is done by evaluating the portfolios under different combinations of future conditions, such as City Light's demand for electricity, the cost of market power, the cost of natural gas and other fuels, and environmental regulations. The IRP process tests candidate portfolios against a range of conditions that might occur in the future, without knowing which set of conditions will actually happen.
- Implementing the long-term resource strategy developed in the IRP. This stage includes acquiring new resources, and may also involve entering into long-term transactions designed to improve the overall balance of loads and resources in the Utility's portfolio.
- Minimizing risk on an ongoing basis. Resource portfolios change over the years, and their output and performance can change daily or even hourly. This presents a significant challenge to Utility resource operators who must make sure City Light has enough electricity to meet demand at all times.

The criterion used to evaluate risk is the relative volatility of variable costs and net revenues across portfolios. Risk is measured for the variable costs of the resource portfolios and for net market purchases and sales. Varying fuel prices and the extent and frequency of plant operation affect variable costs. Net revenues from market purchases and sales are influenced by the extent of surplus generation and the spot market price.

For both the variable cost and net revenue risk, one measure applied is the coefficient of variation. The coefficient of variation is calculated as the standard deviation divided by the mean. It measures the degree of variance from the mean, or average. The greater the variance from average, the larger the coefficient of variation and the larger the implied risk associated with the portfolio. Another risk measure evaluated during modeling of portfolios is what percentage of Monte Carlo iterations fall within the 5 percent and 95 percent tails of the probability distribution.

Minimize Environmental Impact

Air emissions were explicitly included in the modeling and analysis of portfolios because of their importance to the environment and because they can be quantified without specific siting information. For other environmental elements including land use, surface and groundwater, soils and geology, plants and animals, employment, aesthetics and recreation, environmental health and cultural resources, each portfolio was assessed for the level of impact in each element. Each portfolio was ranked high, moderate or low (see Table 6-10 in Chapter 6 and the DEIS Summary).

For each generating resource portfolio, total emissions into the air of carbon dioxide (CO2), sulfur dioxide (SO2), nitrogen oxides (NOx), mercury (Hg), and particulates (PM) are estimated over the 20-year period. A monetary cost is applied to the emissions to approximate the cost of complying with potential environmental regulations in the future. The compliance costs of each portfolio are tabulated by year and expressed as a net present value. These costs are varied in the alternative futures to gain a sense of how well the portfolios perform under different regulatory scenarios. These costs are included in the cost evaluations described above.

Several methods can be used to determine the social costs of environmental impacts such as air emissions. In addition to the internalized cost comparisons, the model calculates net emissions for each resource portfolio (emissions generated minus emissions reductions from sales into the market that result in turning off less efficient resources). In this case, mitigation costs (or control costs) are used as a proxy for the net environmental damage from air pollutants of each portfolio. A cost measure is applied to each type of emissions to evaluate the relative environmental performance of each portfolio.

The method chosen to evaluate environmental costs in the IRP is to estimate the mitigation cost (or control cost) for total emissions of each of the five substances. This approach does not place a value on the damage done by pollutants, but does allow a direct comparison between resource portfolios with respect to estimated cost of mitigating environmental impacts. Environmental mitigation costs of each portfolio are tabulated by year and expressed as a net present value.

Certain assumptions were made in estimating greenhouse gas emissions from the generating resources. Biomass and landfill gas were assumed to have zero net impact on greenhouse gas. They were considered closed-loop systems, where the carbon dioxide emissions are equal to the carbon dioxide captured by the plants and other substances prior to being combusted.

The air emission impacts of market sales and market purchases were accounted for by using Global Energy Decisions forecasts of resources on the margin in the Western power market. City Light market sales were assumed to displace a corresponding amount of energy from the marginal generating unit in the market at the time of the sale. Conversely, market purchases were assumed to be generated by the marginal generating unit at the time of the purchase. Given that Seattle's resource portfolio is mostly comprised of hydropower, market sales could have a significant positive air emissions impact by backing down less efficient Western thermal generators on the margin, most often natural gas-fired turbines.

In evaluating and comparing candidate resource portfolios, the largest factor was frequently the amount of carbon dioxide emitted from a resource portfolio. City Light assumes that carbon dioxide emissions must be offset according to City policy. Presently, carbon dioxide offsets are averaging $5 dollars/ton for City Light, resulting in higher costs for candidate resources consuming fossil fuels.

Using the Model to Evaluate Portfolios

This section describes the analytical tool – the computer model – that City Light used to analyze the candidate resource portfolios. The Planning and Risk model is licensed by Global Energy Decisions (GED). Over several months, staff from City Light and GED worked to capture the features of City Light's existing resources – hydro variability chief among them – in the model, and to describe the operating and financial characteristics of the candidate resources that make up the portfolios.

A complete description of the resources available, the prices of fuel and power, and the load were entered into the model. It then "dispatches" or selects from among the resources available to it to meet the demand it faces each hour of the year. The dispatch is economic, meaning the model uses the cheapest resources first, and then moves up to the next least expensive resource until the demand is met. The model views the wholesale power market as a resource during this process and uses it rather than a physical resource if it is less costly to do so.

The model makes other economic decisions, in particular dispatching resources to sell into the wholesale market when it is profitable. For example, when gas prices are low enough relative to power prices that it is profitable to buy gas and produce power, the model does so. This use of a resource helps to reduce the overall cost of having it in the portfolio.

Dispatch of resources respects all constraints and restrictions on those resources. For example, combustion turbines have ramp up and ramp down rates that must be accounted for in deciding when and how to dispatch them. Similarly, there are minimum and maximum flow constraints for the Gorge project on the Skagit River to protect the fish.

As it dispatches resources, the model keeps track of the cost of operating the resources, a variety of air emissions, and the hours of load not served, among a host of other data. These are used to measure performance against the evaluation criteria.

A key feature of this model is its ability to handle uncertainty about the future – not uncertainty about which, if any, of the four futures identified will actually come to pass, but uncertainty within the futures themselves. The model can generate a sequence of random prices for fuel and power that are centered around the average price for the variable question in any of the futures.

Example Model Operation and Output

As an example of how the model works, consider the Mid-Columbia wholesale market peak price for power under the "Reference Case" future shown in Figure 5-5. In January 2010, the forecasted on-peak price is just under $38 per megawatt-hour. However, from the model's perspective, that is just the center of the distribution of market prices for power in that month for that particular future.

Figure 5-5. Mean Mid-Columbia On-Peak Power Prices, 2007-2026

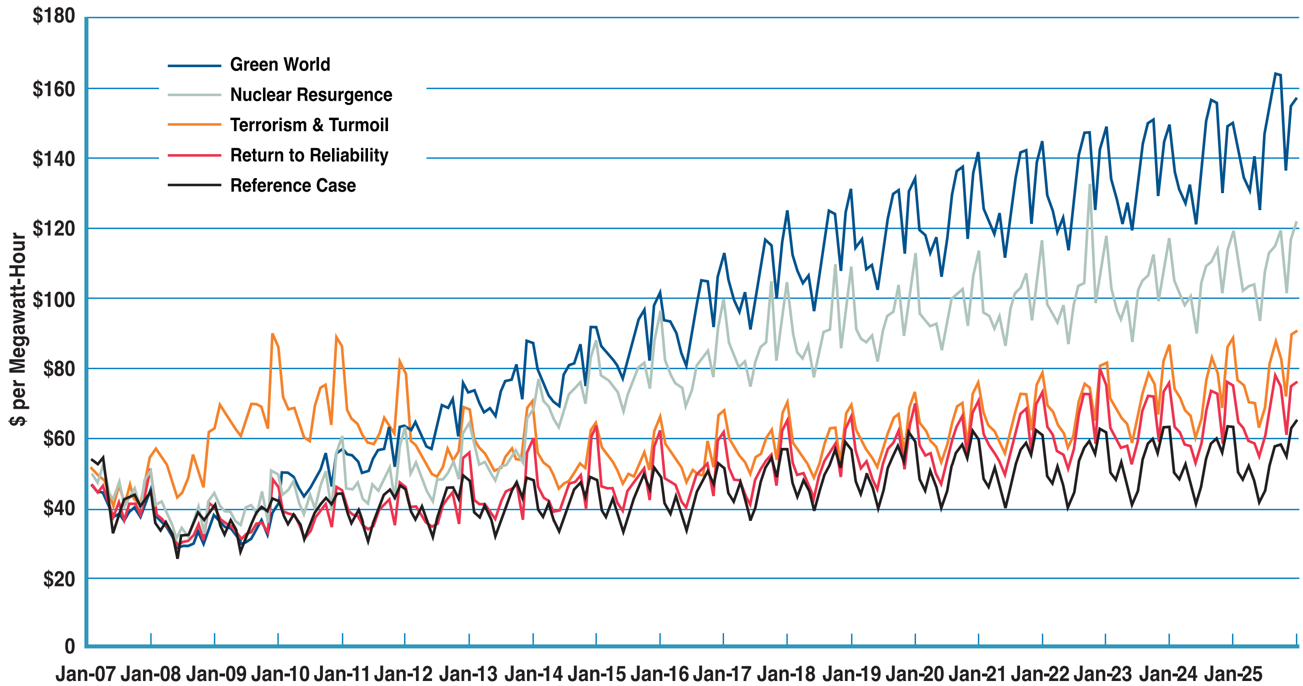


Figure 5-6 shows price distribution the model generated around that center point. The model is able to generate similar distributions for all prices in the model.

Figure 5-6. Typical Power Price Distribution

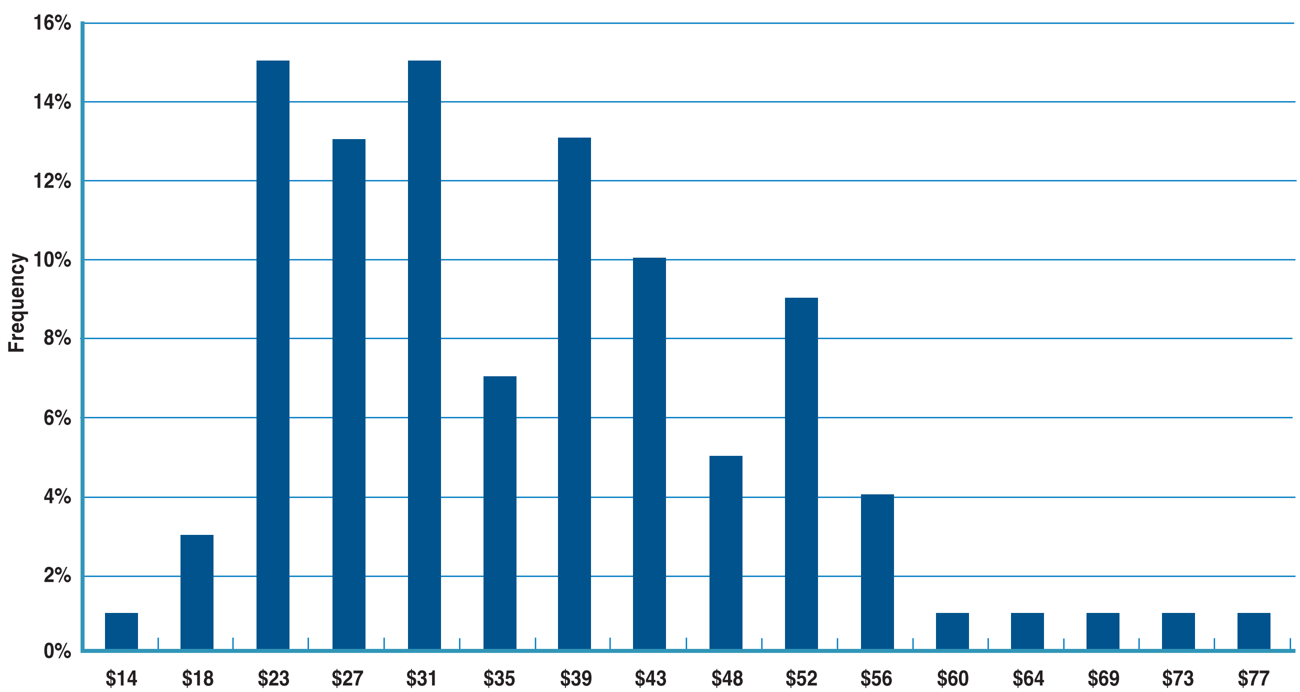
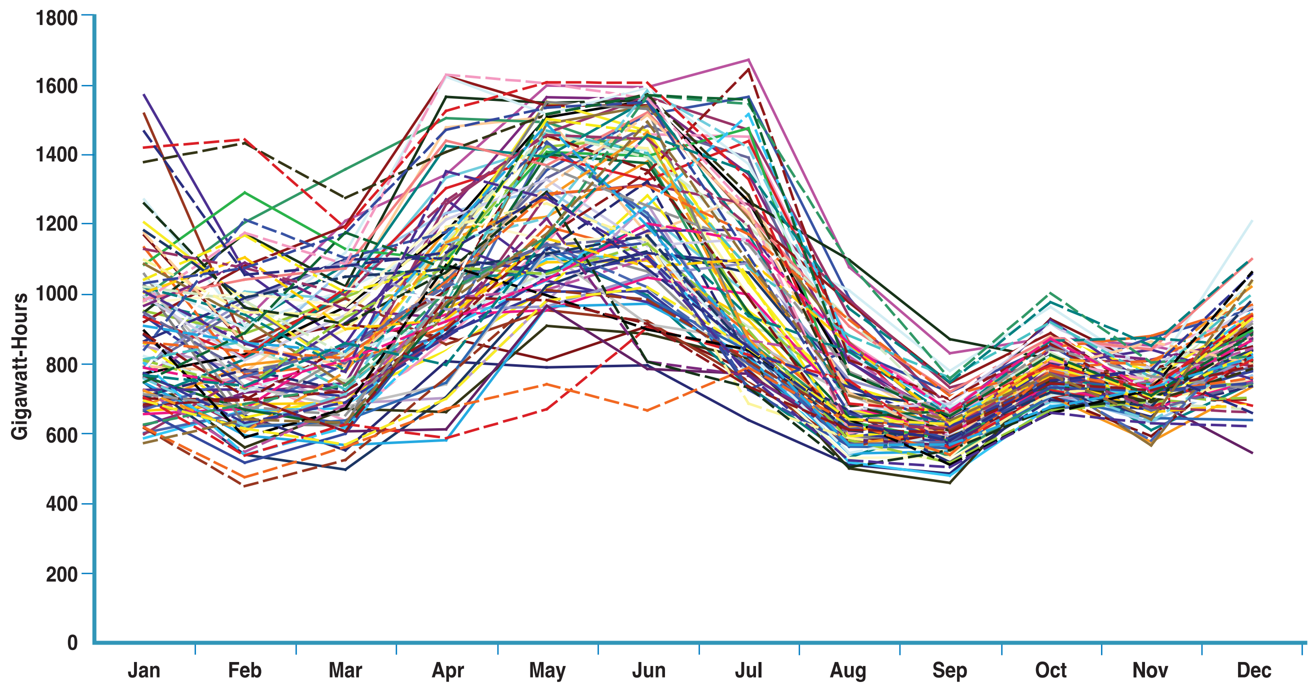


Figure 5-7. Hydro Variability



However, prices are not the only source of uncertainty. Customer demand and, critically for City Light, availability of water for generation are also uncertain. Much of the effort in modeling City Light's system went into "teaching" the model about the variability of hydro generation. Figure 5-7 shows the model-generated distribution of generation for City Light's hydro system. The pattern it produces, made up of randomly generated water years, is similar to the pattern exhibited by the historical record. However, the model is not limited to the historical record either in terms of number of years – it can produce as many water years as needed – or in terms of the range of possible water years.

Constraints in the Model

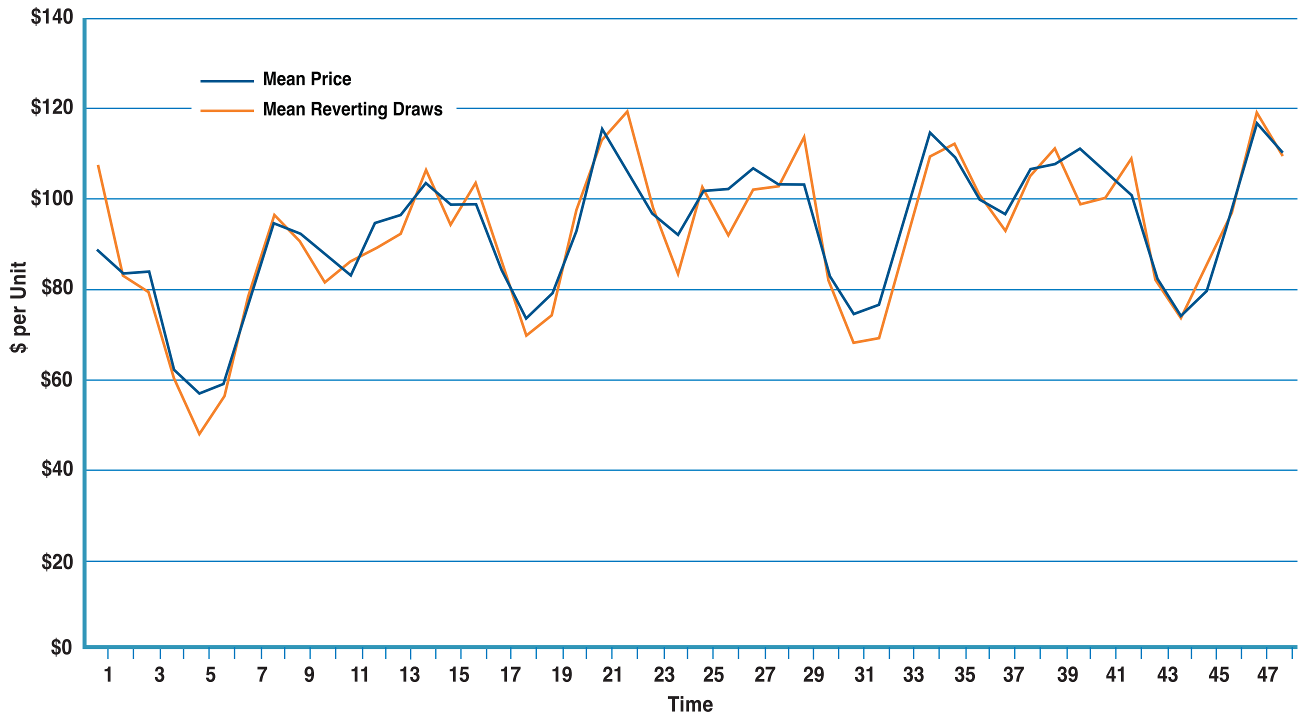
As described earlier, effects of uncertainty are captured in the model by having it make random selections, or "draws" for key outcomes. This is analogous to drawing cards from a well-shuffled deck, but adding each card drawn back to the deck and reshuffling it again before each new draw. The draws are made from many potential outcomes of fuel prices, power prices, generation and loads. The result of each new draw is equally likely to results of previous draws.

In producing the draws of fuel prices and power prices, generation and load, the model is constrained in several ways. First, relationships exist between power prices and fuel prices. This is not surprising since fuels like natural gas and coal are used to produce power. All things being equal, higher fuel prices lead to higher power prices. Of course, fuel prices themselves often move in tandem.

Second, because of the size of the hydro system in the Northwest, during the runoff period (April to June) wholesale market prices for power are often depressed as the hydro system displaces fossil fuel generation in the region. The effect is relatively short-lived, but it is important.

These correlations among the variables in the model must be accounted for when creating a sequence of, for example, prices for market power. That sequence cannot be entirely free and unconstrained, but must reflect the relationship to the draws for natural gas, hydro generation and other variables. City Light estimated several of these correlations from historical data and GED provided the others.

Figure 5-8. Mean Reverting Random Processes



The final constraint is particularly important when creating the draws of prices. The draws must not only respect the correlations noted above, but must also mirror the pattern of prices actually observed in the markets for fuels and power. These prices exhibit a pattern called mean reversion, meaning that although they vary randomly, they tend over time to return to some central value. Figure 5-8 shows an example of a sequence that exhibits mean reversion. Although the sequence in yellow bounces around, it does not stray too far from the underlying mean of the variable, in blue.

Energy prices behave very like those in Figure 5-8. The reason is that underlying the markets for fuel and power are real, physical processes driving the demand and supply for the commodity. These fundamentals determine, within reason, the limits to the size and duration of price excursions. The energy crisis of 2000-2001 is a notable exception; however, in that case, the usual market mechanisms were frustrated by gaming of the system.

Analysis

For each time step in the analysis, the model generates a set of correlated values for prices, load and generation, and dispatches the resources as described earlier. It repeats this process 100 times before moving to the next time step. In this way, instead of a single value for an output of the mode for a given time step – for example, the cost to operate the portfolio or the amount of carbon dioxide emitted – the model produces a distribution for each output. Those distributions reflect the underlying distributions and correlations for prices and other variables.

This approach to analysis, often called a Monte Carlo simulation, gives very robust results in the sense that they capture more fully the underlying uncertainties in the process. The ability of the underlying drivers of the analysis to vary randomly and in a way not directly controlled by the modeler is key. While the modeler can set the parameters of the random process – the center and spread of the distribution and its correlation to other drivers – the model selections themselves are random.

Additional details on the methodology underlying the draws are in Appendix D.

Selecting Portfolios for Analysis

Integrated resource planning involves examining a wide range of alternative resources. Washington State law (HB 1010) requires City Light to "perform a detailed and consistent analysis of a wide range of commercially available resources," including conservation. Three key objectives were considered in constructing the resource portfolios:

- Develop a wide range of resource portfolios, including those containing predominantly renewable resources, those containing predominantly non-renewable resources, and those with a mixture of renewable and non-renewable resources.
- Ensure sufficient supplies of generation each month during the 20-year period to avoid unserved energy needs with a 95-percent degree of confidence.
- Utilize a mix of resources believed to be commercially available to City Light and resources specifically recommended for inclusion in the portfolios through the public input process.

For the first round of analysis, City Light developed nine portfolios of new resources that in principle would be able to fill the resource gap determined by the resource adequacy study. Based on these results, eight new portfolios were defined for analysis in the second round. The resources listed below and described in Chapter 4 were used in various combinations to define the portfolios.

Additional Conservation

Renewable Generation

- Hydro (hydro contract, Gorge Tunnel hydro-efficiency improvement).
- Wind.
- Geothermal.
- Biomass.
- Biogas (landfill gas).

Non-renewable Generation

- Natural gas – Combined-cycle combustion turbine (CCCT), combined heat and power combustion (CHP), simple-cycle combustion turbine (SCCT).
- Coal – Pulverized coal and integrated gasification combined cycle (IGCC).

Mixed resources

- Seasonal exchanges, seasonal call option.
- Bonneville Power Administration (BPA) – 100 percent Block, 50 percent Block, 50 percent Slice.

Market resources

- Wholesale power market.

The next chapter describes in detail the Round 1 and Round 2 portfolios, and results of the analysis.